Shallow-Water Reverberation and Seabottom Acoustic Parameters

J. X. Zhou
School of Mechanical Engineering
Georgia Institute of Technology
Atlanta, Georgia 30332-0405
Tel: (404) 894-6793 Fax: (404) 894-7790 Email: jixun.zhou@me.gatech.edu

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LONG-TERM GOALS

The long-term goals of this work are: to develop a theoretical model for predicting reverberation in shallow water, to derive small-angle seabed scattering strength, sound velocity and attenuation in sediments from reverberation and propagation data at low frequencies, and to understand the physical mechanisms of sea bottom scattering.

SCIENTIFIC OBJECTIVES

The scientific objective of this research is to investigate the effects of the sea bottom on sound propagation, reverberation and signal coherence in shallow water for a frequency range of 100 Hz-3000 Hz. Our specific objectives are (I) to derive acoustic parameters in sediments from both sound propagation and reverberation data. And (II) to characterize the seabottom scattering function from reverberation and propagation measurements.

BACKGROUND

In shallow water, reverberation can often be the limiting factor on the operation of active sonar systems. In spite of this, long-range reverberation models have not been as well developed as propagation loss models. One of the reasons that the development of these models has lagged is the dearth of experimental data for low frequencies and shallow grazing angles. Grazing angles of primary importance to shallow water applications range from about 20° to near 0° with the smaller angles being more important. Direct measurement of bottom scattering strength at small grazing angles and low frequencies in shallow water is nearly impossible. Therefore, the bottom scattering strength at small grazing angles is generally derived from long-range reverberation measurements. However, reverberation-derived seabottom scattering inevitably includes uncertainties due introduced by the lack of reliable sound velocity and attenuation in the sediments in a given measurement area.

In the Yellow Sea 96 experiment and the ASIAEX 01, wide-band sound propagation and reverberation data were collected by vertical arrays of hydrophones. These data can be used to derive acoustic parameters in sediments (velocity and acoustic attenuation) and bottom scattering function. The data can also be used to test the sensitivity of the inversion procedures to the uncertainty of the sediment parameters.

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14. ABSTRACT
The long-term goals of this work are: to develop a theoretical model for predicting reverberation in shallow water, to derive small-angle seabed scattering strength, sound velocity and attenuation in sediments from reverberation and propagation data at low frequencies, and to understand the physical mechanisms of sea bottom scattering.

15. SUBJECT TERMS

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APPROACH

A normal-mode reverberation model will be used to calculate the shallow-water reverberation field. To decrease the uncertainty of reverberation-derived seabed scattering, several measures can be taken into account in our inversion process. For example, both average reverberation level (RL) and reverberation spatial coherence data will be simultaneously used to characterize the seabed scattering (as a function of frequency and angle). Propagation-derived acoustic parameters in sediments will be used to check the reverberation inversion results. In the first phase of this research, semi-empirical seabottom scattering models such as the Lambert law and Lommel-Seeliger law will be used for the normal-mode reverberation model. Theoretical models of seabottom scattering with more physical bases will be used later in our analyses.

RESULTS

From the Yellow Sea '96 experiment and ASIAEX 01, both wide-band propagation and reverberation data were collected by vertical hydrophone arrays. Reverberation intensities as a function of time, frequency and receiving depth have been obtained. We have analyzed vertical cross-correlation coefficients of reverberation as a function of time, frequency and separation between a pair of hydrophones.

Fig. 1 shows that both Lommel-Seeliger law ($BS1 = \mu_1 \sin\theta$) and Lambert law ($BS2 = \mu_2 \sin^2\theta$) can fit a measured reverberation curve, obtained from the Yellow Sea. Two numerical reverberation curves were obtained with same density and same sound velocity, but different acoustic attenuation in the sediments. This means that uncertainty in seabed scattering strength from long-range reverberation data is mixed with uncertainty of the seabottom acoustic attenuation in an experimental area. Thus, to derive seabed scattering at small grazing angles from long-range reverberation, it is critical to have ground truth measurements of sound speed/attenuation in sediments.

Fig. 2 shows vertical cross-correlation coefficients as a function of frequency and time at the Yellow Sea '96 site, averaged from six pairs of hydrophones. Both sound sources and receivers were located below the thermocline. The hydrophone separation is 2 m.

Fig. 3 shows the sound velocity profile during the reverberation measurements at the ASIAEX site on June 5. Reverberation levels obtained from whole water column at 1000 Hz are given in Fig. 4. Fig. 5 shows vertical cross-correlation coefficients as a function of reverberation time and frequency in the East China Sea. These results with sound propagation data will be compared with numerical simulations on reverberation, and be used to characterize the seabottom scattering function and to derive acoustic parameters in the bottom.

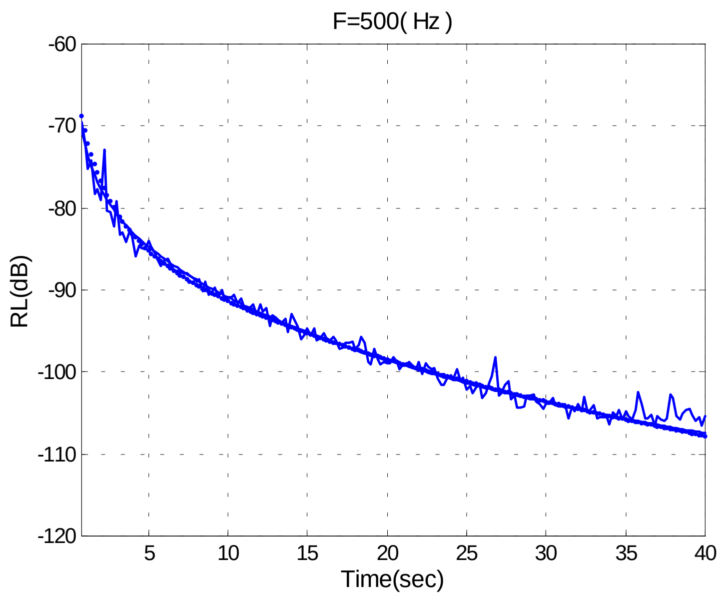

Fig. 1 Both the Lommer-Seeliger law (solid line) and the Lambert law (dotted line) may explain the RL decay curve. The same seabottom acoustic parameters are used for numerical modeling but a different acoustic attenuation in the sediments has been selected for each case.

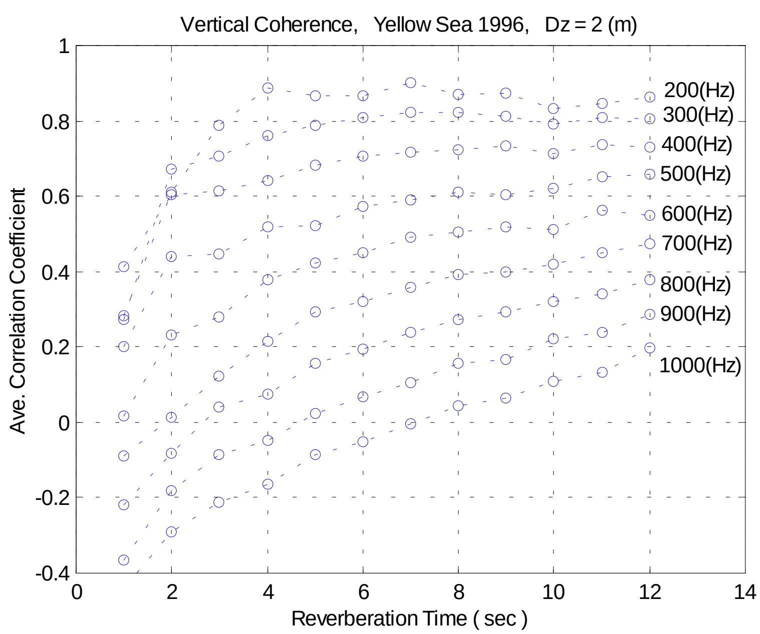

Fig. 2 Vertical cross-correlation coefficients as a function of frequency and time at the Yellow Sea '96 Site. Both sound sources and receivers were located below the thermocline. The hydrophone Separation is 2 m.

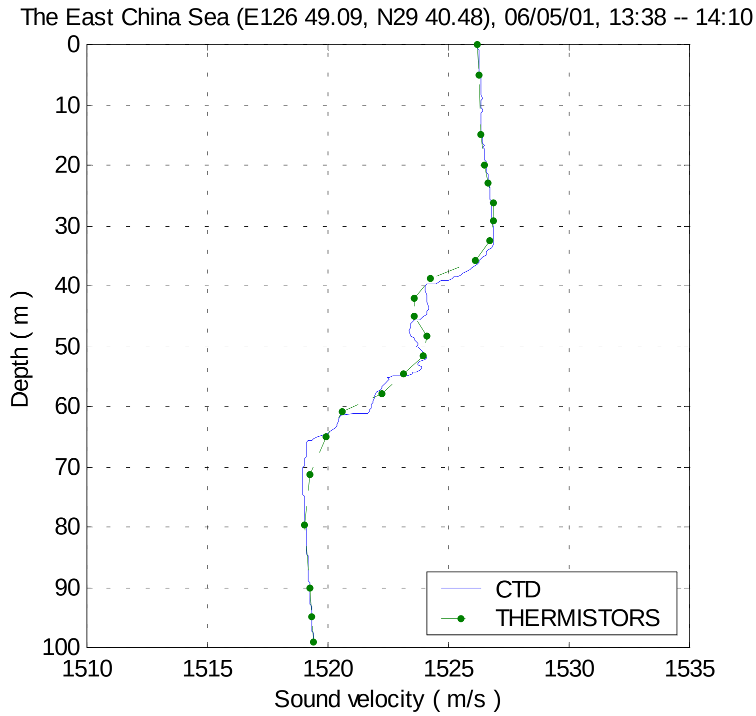

Fig. 3 The sound velocity profiles during the ASIAEX reverberation measurement period on June 5.

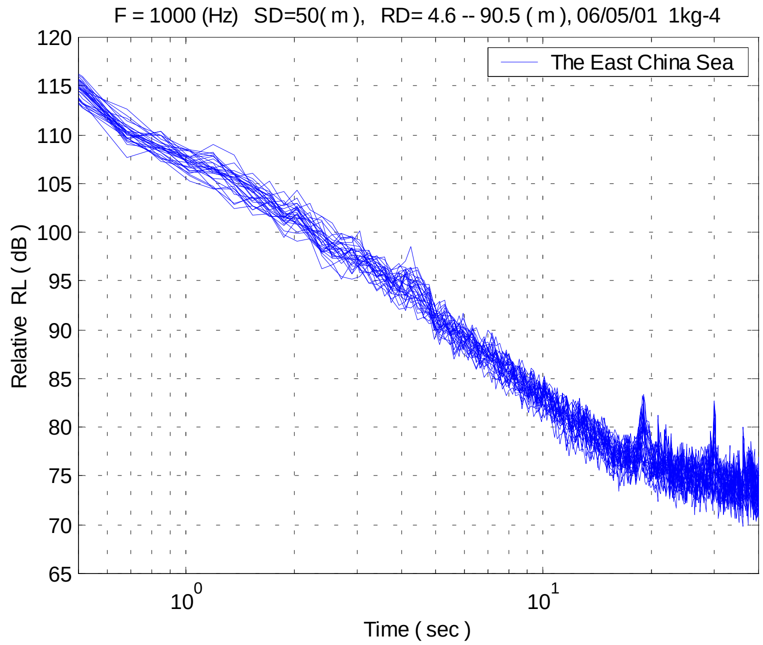

Fig. 4 Reverberation intensity vs. time, obtained from ASIAEX in the East China Sea.

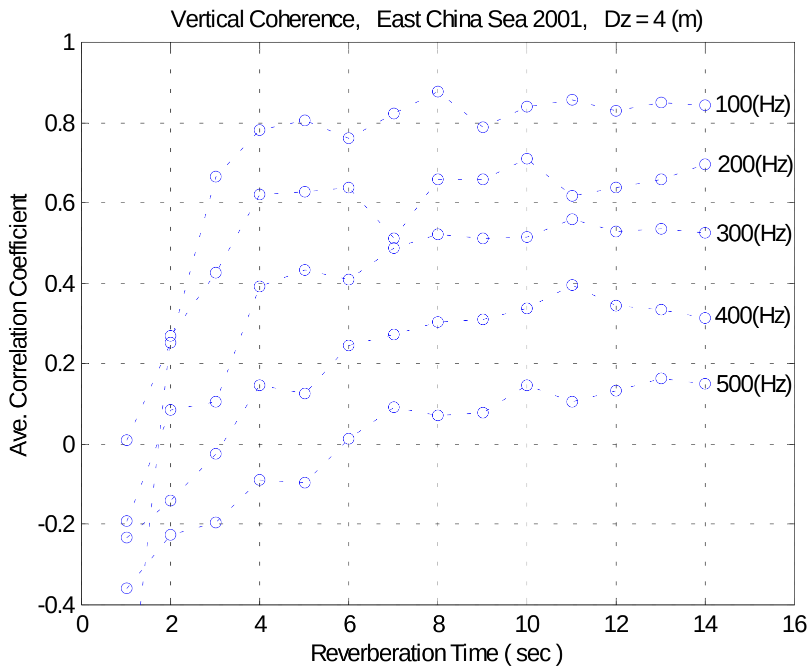

Fig. 5 Vertical cross-correlation coefficients vs. reverberation time and frequency at the ASIAEX site. Source depth: 50 m. Receivers' depth: 56.5 –80.5 m. Hydrophone separation: 4 m